Blockchain Technology in Healthcare Information Systems

(Technologia Łańcucha Bloków (Blockchain) w Systemach Informatycznych Opieki Zdrowotnej)

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Abstract – Introduction. The foundation of an effective model of health care is an efficient IT system. Nevertheless, over half a century of evolution of technological solutions used in such systems did not fully bring expected results. What is more, the implementation of extremely fast developing ICT technologies in the health care sector does not translate into a significant improvement in its quality, effectiveness and cost reduction. One of the currently developing concepts for solving the above problems may be the use of blockchain technology..

The aim of the study. The aim of the study was to present selected issues, examples and perspectives of blockchain application in healthcare.

Selection of material. The search was conducted in the Scopus database using the following terms: blockchain, IT system, healthcare 2018-2019. The literature found in the Google Scholar database was analyzed in terms of the highest number of quotations. Such selected literature was used as a material for the preparation of the present paper.

Conclusions. Blockchain technology is a particularly welcome solution at a time when traditional "endpoint" protection in information management systems is losing its meaning. Despite the fact that the concept and methodology describing the model of information processing in the chain of blocks has a known characteristic, its embedding in information management processes in the Polish healthcare system is still at an early stage.

Key words **-** blockchain, information system, healthcare.

Streszczenie – Wstęp. Fundamentem efektywnego modelu opieki zdrowotnej jest sprawnie funkcjonujący system informatyczny. Niemniej jednak ponad pół wieku ewolucji rozwiązań technologicznych wykorzystywanych w takich systemach nie przyniosło w pełni oczekiwanych rezultatów. Co więcej, implementacja niezmiernie szybko rozwijających się technologii ICT do sektora ochrony zdrowia nie przekłada się na istotną poprawę jego jakości, efektywności oraz redukcji kosztów. Jedną z aktualnie rozwijających się koncepcji na rozwiązanie powyższych problemów, może być użycie tzw. technologii *blockchain.*

Cel pracy. Celem pracy było przedstawienie wybranych zagadnień, przykładów oraz perspektywy zastosowania *blockchain* w opiece zdrowotnej.

Dobór materiału. Poszukiwania przeprowadzono w bazie Scopus używając pojęć ***:*** *blockchain, system informatyczny, opieka zdrowotna* 2018-2019r. Znalezione piśmiennictwo w bazie Google Scholar przeanalizowano pod kątem największej liczby cytowań. Tak wyselekcjonowane piśmiennictwo posłużyło za materiał do opracowania niniejszej pracy.

Wnioski. Technologia *blockchain* stanowi szczególnie oczekiwane rozwiązanie w czasach, gdy tradycyjna ochrona „punktu końcowego" w systemach zarządzania informacją traci swój dotychczasowy sens. Pomimo, że koncepcja i metodologia opisująca model przetwarzania informacji w łańcuchu bloków posiada znaną charakterystykę, to jej wbudowanie w procesy zarządzania informacją w polskiej opiece zdrowotnej znajduje się jeszcze na wczesnym etapie.

Słowa kluczowe – blockchain, system informatyczny, opieka zdrowotna.

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A. The idea and the planning of the study
B. Gathering and listing data
C. The data analysis and interpretation
D. Writing the article
E. Critical review of the article
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I. INTRODUCTION

A well-functioning IT system is the basis for the proper functioning of the health care system. Despite over 50 years of development of computer systems and application of various technological and software solutions in health care, their relatively low application and practical use are still a significant problem. The expected improvement in quality, effectiveness and cost reduction is not observed. 1,2] Medical entities and institutions providing medical services in Poland are obliged to document them both for therapeutic and evidentiary purposes in case of events resulting in the patient or his or her questioning the correctness of the procedures granted. The provisions of the law have regulated in detail the principles of keeping medical records of their content, as well as the periods of storage (Article 29(1)). [3]

Workers in the health care sector in Poland use digital information and communication technologies to a large extent. According to the data from the report (Future Health Index, 2019), as many as 77% of medical staff representatives use at least one digital solution (including mobile applications) in their practice or hospital. In turn, 64% of medical staff representatives from large (employing 50-199 employees) and very large (over 200 employees) medical facilities shared data on patients with other representatives of medical staff in their facilities. Still, only 11% of healthcare professionals share patient data electronically with other healthcare professionals outside their facility. [4]

The technological solutions used currently in the health care system to collect and process data contained in medical records are very different and depend to a large extent on the software provider. The consequence of this state of affairs is the lack of interoperability of systems used in the health information system. As a result, it is not possible to use the documentation kept by other entities during the patient's visit. Each clinic, hospital, diagnostic laboratory keeps its own documentation and the only possibility of supplementing data in medical documentation is to provide the documentation by the patient and enter the data contained therein by the entity providing the service into its own documentation. Due to the fact that IT systems used for keeping medical records in particular units are not interconnected [5], the challenge for decision-makers responsible for the shape of the information system in health care is to continue work on the system that would enable gathering information on services provided for a given patient and indicating the place of storage of his/her medical records.

In Poland, benefits provided by entities having contracts with the National Health Fund (NFZ) are recorded. A register of services provided for a given patient is kept. It is controlled by one institution - the National Health Fund. Apart from the NFZ, the patient has access to data through the Integrated Patient Information System (ZIP). 6] Work is underway to extend the scope of the register to include services provided by healthcare providers who do not have a contract with the NFZ. The place of obtaining information on, among others, procedures performed and medicines purchased is the Individual Patient Account. 7] The construction of such a defined system raises many practical problems. They concern such issues as system security, permanent data storage (electronically), high costs of systems, availability (identification and authorization) and making data available to other entities.

One of the new concepts that may revolutionize the solution to these problems may be the use of blockchain technology. In this area we can see interest of international decision makers (European Union) and national decision makers (Poland), by creating strategies and expert teams. In this article we present selected issues, examples and perspectives of blockchain technology application in healthcare.

II. DEFINITION OF BLOCKCHAIN

Blockchain is one of the solutions belonging to a wider group of Distributed Ledger Technology (DLT) technologies - replicated, shared and synchronized digital data spread across multiple locations, countries and/or institutions. 8] Blockchain, translating from English to Polish, is a chain of blocks (or block chain), but there is much more to it. Well, blockchain is actually a distributed database containing records or a public record of all transactions and digital events that have been carried out and then made available to the participating parties. The technology was first introduced with the Bitcoin cryptographic currency. However, blockchain can be a stand-alone system - no

cryptographic currency is needed. Due to its design it can be used in many different sectors (industrial, commercial, health, etc.). Blockchain is a register of blocks marked with a time stamp (unchangeable marking containing the exact date of modification). Each block has two main components: (1) data and (2) reference to block previously in abbreviated form. This structure creates a connection between the blocks in the blockchain. [9]

The assumptions of blockchain technology require an infrastructure to create a decentralized public transaction log that provides security, anonymity, and tamper-resistant encrypted data. This has attracted the interest of large technology companies such as IBM Watson and Microsoft, who are working to deliver Blockchain-as-a-Service (BaaS) products, where programmers can create and test a block chain in the cloud. 10] In addition, in 2017, Pfizer and other pharmaceutical companies also supported the first major project (MediLedger) in the United States to develop blockchain technology specifically for pharmaceutical supply chains. [5]

Blockchain technology has the potential to play a key role in improving the healthcare sector. Application is seen in areas such as public health management, chronic patient monitoring, automatic judgement on health claims, online access to health records for patients, sharing of medical data, personalised medical research, prevention of drug counterfeiting and clinical trials. The management of Electronic Health Records (EHR) is probably the area with the highest growth potential. [11]

III. SMART CONTRACT

An innovative solution based on blockchain is the possibility of replacing a trusted third party (e.g. office) with a technology that guarantees the correctness (by appropriate checking algorithms) of the entered data in the register and the inability to make any changes after saving the data. This algorithm automatically blocks entries that are inconsistent with copies registered on other computers of the system creating the block chain, using the criterion of assessing evidence of data validity (Figure 1.). The technology described in this way is called smart contracts and enables automatic execution of the agreement after meeting the conditions specified in the contract. An example of an intelligent contract may be the cost of private health insurance calculated in real time, depending on the number of services used by the patient. The technology of intelligent contracts is not free from weak points, because errors may occur in the program code and it should be remembered that once entered, even untrue data will be recorded permanently. [8]

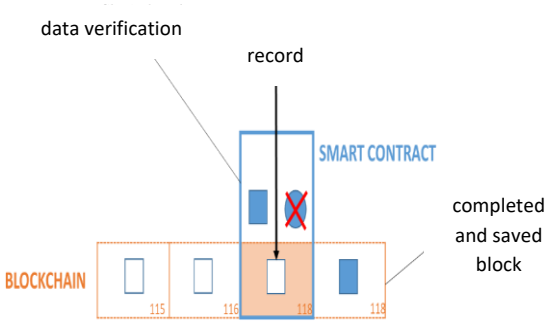

Figure 1. Smart contract operation scheme [own work]

There are also ideas to use smart contracts in a way that can alert doctors and hospitals if a patient's condition deteriorates or in situations where a doctor's access to devices worn by patients requiring special care is approved, to perform measurements or to view data in real time. Smart contracts could also ensure that the supply chain of medicines is tracked and alerted if the patient receives the wrong medicines or is not being treated properly. [9]

IV. BLOCKCHAIN AS A NEW QUALITY IN THE HEALTHCARE INFORMATION SYSTEM

The specificity of medical data; their volume, their extraordinary diversity, multimedia and importance (e.g. in life-threatening emergencies), and on the other hand the legal aspects of personal and sensitive data may cause difficulties in developing a satisfactory health information system. The organisational system and the wide variety of entities participating in the system, as well as the heterogeneous financing rules, further complicate the problem. The fundamental difficulty is the lack of appropriately efficient structures allowing for collection and storage of medical data by medical institutions allowing for easy, fast, safe and lawful access. [12]

Blockchain technology is designed to change the effectiveness, efficiency, safety and transparency of healthcare through:

- create secure, patient-centred data structures that are accessible and controllable by patients - their

identification data can be deleted for research and statistical purposes,

- invariability (stability) of the documentation for each patient - the data are secured and their authenticity is guaranteed,
- data is secure - stored in multiple locations,
- greater transparency of processes if data is stored and accessible to all actors in the healthcare system,
- faster access to healthcare - data is directly accessible to healthcare providers,
- reduction of costs through direct access to medical data and, for example, elimination of a large number of unnecessarily repeated tests. [12]

V. RODO REGULATIONS - PROTECTION OF PATIENT DATA IN BLOCKCHAIN TECHNOLOGY

The widespread use of blockchain technology in Europe is still hindered by ambiguous legislative issues arising primarily from the RODO (General Data Protection Regulation) regulation. Once recorded in a chain of blocks, the data cannot be deleted, and this is in conflict with the right of use to "be forgotten", i.e. the right to delete data about yourself from a given directory. However, due to the fact that this article refers to medical data, there is a provision that says that there is a possibility to derogate from the provision to be forgotten if the processing of data is necessary for public health activities, management of health care services or social security services. In addition, an exception is made for archival, statistical, scientific and historical purposes in the public interest and for the establishment, investigation or defence of judicial claims (paragraph 52 RODO). [13]

In addition, the right to be forgotten does not always mean the permanent deletion of data: The methods of limiting the processing of personal data may include, among others: temporary transfer of selected personal data to another processing system, preventing users from accessing selected data, or temporary deletion of published data. (§ 67 RODO). [13] With this in mind, it can be assumed that blockchain systems can use a method that allows the "forgetting" of user data without permanent deletion, which in fact blockchain is impossible. Another possibility is to store sensitive (personal, medical) data outside blockchain and only have links (addresses) to these data in blockchain. The deletion of sensitive data would not affect the structure of the blocks and could provide a sufficient solution to a request for deletion of personal data. [8]

An important point of emphasis is the obligation to identify the controller. In many different situations, but above all in case of data leakage and legal liability, it is important to be able to indicate who is responsible for the system and the data contained therein. Such an unambiguity does not exist in the blockchain system, because each user has the same block of data and has the function of a processor (the entity responsible for processing the data).[8] So far, there is no solution to this issue in the scientific literature.

Emerging events related to large scale personal data breaches (e.g. in hospitals) encourage a reassessment of data management including the introduction of more precise risk-based methodologies as proposed in the RODO report. In this sense, it would be advisable to use technologies, such as the block chain, to implement tools for safer and more transparent data management. [14]

VI. RESTRICTIONS AND UNCERTAINTIES OF THE BLOCKCHAIN SYSTEM

Despite so many practical benefits and expected functionalities associated with the use of "blockchain blocks" it is worth remembering that blockchain is not a "technological panacea" to be applied to any data processing process. Sometimes, in certain areas, better results can be achieved using traditional decentralised systems. 15] Below are some examples of blockchain limitations compared to such systems. The first one is a relatively slow verification of the validity of the transaction in the blockchain system, which results from the need to confirm this fact by all network participants. The second one is related to the susceptibility of the "blockchain" system to the so-called 50%+ attack. It consists in initiating the change of the executed transaction by artificially creating another block with a transaction with a different addressee, and then forcing the recognition of the new path as the dominant one for the whole chain. Another drawback of the concept of "integrated data dispersion" results from the very nature of the blockchain system - it is a fast growing size of blocks in which each participant of the system stores a complete history of all transactions. At the same time, the size of the entire system increases with each new block.

When processing patient health data using public blockchain systems, there may be many serious problems and uncertainties with the limited level of control over the operation of the system in terms of ensuring the security of transactions. Moreover, users of such a system remain

anonymous and their actions cannot be governed by a forced code of conduct. Another problematic specificity of blockchain from the point of view of health care is the shifting of the burden of storing authentication data to the users of the system. Blockchain does not have a systemically embedded central control panel for managing the keys of its users, which authenticates access to individual digital resources (each user may have multiple private keys). Unfortunately, if such a key is lost, all sets of information assigned to it are lost practically without the possibility of their recovery. This is associated with a further restriction on identity management using digital signatures. The process of verifying a signature during the transaction itself connects transactions with the owners of private keys - however, this does not mean that real identities can be linked to these owners.

Building a conscious user perspective with respect to the blockchain system functionality, especially in the case of healthcare, seems justified by the necessity and conduct of choice. Certainly, the use of the blockchain method in the process of data processing means a real technological breakthrough, but due to the above-mentioned limitations blockchain in the opinion of the authors should not be completely abandoned proven / traditional methods of data processing.

VII. CONCLUSIONS

According to experts, efficient, comprehensive exchange of information between all participants of this system will not only improve therapeutic and cost effectiveness, but will also allow patients to consciously manage their health. In the long-term perspective, it will contribute to the increase in the quality of services in the Polish health sector. A similar position is taken by representatives of the patient community. According to its representatives, modern, effective and personalized health care is based on digitalization, digitalization and data analysis, and access to information - for both the patient and the doctor - allows to build relationships based on trust and partnership, thus improving the process of making correct diagnoses, planning treatment and monitoring health condition. Integrated access to medical data is particularly important in the face of an ageing population.

Blockchain technology is a particularly expected solution in times when the traditional "end point" protection in information management systems loses its current meaning. However, although the concept and methodology describing the model of information processing in the chain of blocks has a known characteristic, its embedding in the information management processes in the Polish healthcare system is still at an early stage. Bearing in mind the reasons for this state of affairs, mainly related to the arrangement of system solutions and the constant complications of computerization of health care (with particular emphasis on the key functionality of electronic medical documentation), it is worth remembering that blockchain brings a completely new perspective on the functioning of the information system in health care.

VIII. REFERENCES

[1] Centrum Systemów Informacyjnych Ochrony Zdrowia. Badanie stopnia informatyzacji podmiotów wykonujących działalność leczniczą, III edycja. [online] [cited 2019 August 9] Available from: URL:https://www.csioz.gov.pl/edm/

[2] Frączkowski K. Systemy informacyjne oraz usługi w ochronie zdrowia oparte na technologiach SOA (Service Oriented Architecture). Acta Bio-Opt Inform Med Inż Biomed 2010;Vol. 16:81–6. [online] [cited 2019 August 9] Available from: URL:http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-article-BSL7-0039-0013.

[3] Sejm. Ustawa z dnia 6 listopada 2008 r. o prawach pacjenta i Rzeczniku Praw Pacjenta (Dz. U. 2009 Nr 52 poz. 417). Future Health Index 2019, Raport krajowy – Polska. [online] [cited 2019 July 30] Available from: URL:www.philips.com/futurehealthindex-2019.

[4] Rutschman AS. Healthcare Blockchain Infrastructure: A Comparative Approach. *All Faculty Scholarship*. [online] [cited 2018 January 2] Available from: URL:https://scholarship.law.slu.edu/faculty/92.

[5] ZIP. Zintegrowany Identyfikator Pacjenta. [online] [cited 2019 August 9] Available from: URL:https://zip.nfz.gov.pl/ap-portal/user/menu/open@info?view=001.

[6] IKP. Internetowe Konto Pacjenta. [online] [cited 2019 August 9] Available from: URL:https://pacjent.gov.pl/.

[7] Polska Izba Informatyki i Telekomunikacji. Blockchain w Polsce. Możliwości i zastosowania. 2018. [online] [cited 2019 July 10] Available from: URL: https://www.piit.org.pl/wazne/raport-piit-blockchain-w-polsce.-mozliwosci-i-zastosowania.

[8] Simić. M, et al. A Case Study IoT and Blockchain powered Healthcare. Novi Sad, Serbia,: : University of Novi Sad, Faculty of Technical Sciences 2017. [online] [cited 2019 July 10] Available from: URL:https://www.researchgate.net/publication/317433655_A_Case_Study_IoT_and_Blockchain_powered_Healthcare.

[9] Mwashuma EW. Towards universal healthcare coverage through adoption of blockchain technology: a literature review. 2018;5:1-5. http://dx.doi:10.12856/JHIA-2018-v5-i2-205.

[10] Casino F, Dasaklis TK, Patsakis C. A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telematics and Informatics* 2019;36:55–81. http://dx.doi:10.1016/j.tele.2018.11.006.

[11] Blockchain Technologies - Blockchains, Cryptocurrencies, Smart Contracts. Blockchain Technologies. [online] [cited 2019 July 31] Available from: URL:https://www.blockchaintechnologies.com/.

[12] Parlament Europejski. Rozporządzenie Parlamentu Europejskiego i Rady (UE) 2016/679 z dnia 27 kwietnia 2016 r. w sprawie ochrony osób fizycznych w związku z przetwarzaniem danych osobowych i

w sprawie swobodnego przepływu takich danych oraz uchylenia dyrektywy 95/46/WE (ogólne rozporządzenie o ochronie danych).

[13] Marenco M. A Nordic way to blockchain in healthcare | HIMSS Europe. Healthcare Information and Management Systems Society. [online] [cited 2019 July 23] Available from: URL:https://www.himss.eu/himss-blog/nordic-way-blockchain-healthcare.

[14] Vaskovskyi E. Technologia blockchain – możliwości zastosowania. Ośrodek Badań i Analiz Systemu Finansowego. Warszawa; Alterum, 2018.